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ABSTRACT

Samples of clay from two deposits near Wild Cove, Newfoundland, were submitted by the Department of Mines and Energy, Government of Newfoundland and Labrador, for evaluation of their potential for the manufacture of clay products, in particular clay bricks.

Sample No. 002 is extremely plastic. Upon extrusion under vacuum it showed severe laminar flow properties, such that the corners were stripped completely from the extruded column. Even if bricks of mechanically sound appearance could be produced by the usual remedial methods, it is likely that die and auger laminations would develop planes of weakness subject to spalling under freeze-thaw conditions. In addition, the material shows an unacceptably high combined drying and firing shrinkage and a short firing range for products of the degree of vitrification required for exposure to the climatic conditions prevailing in western Newfoundland.

In contrast, Sample No. 005 is of minimal plasticity consistent with good extrusion owing to its high content of fine sand and silt: although the extruded column is of excellent mechanical appearance it is weak (poorly bonded) and would undoubtedly be subject to marking or deformation during handling, either manual or mechanical. The material fires to an excellent brick red at Cone 02 (1101°C, 2014°F) and indicates an acceptably wide firing range below this temperature.

An additional trial was conducted with a 50/50 wt % mixture, demonstrating the influence of each to negate the undesirable properties of the other. In this mixture, the properties of Sample No. 002 dominate, and an appropriate ratio of 2:1 of No. 005:No. 002 is suggested.

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INTRODUCTION

A request was received from Paul L. Dean, Senior Geologist, Mineral Development Division, Department of Mines and Energy, Government of Newfoundland and Labrador, to evaluate the ceramic properties of two samples of clay from Wild Cove, near Cornerbrook in western Newfoundland. The principal objective is to establish a resource base for a brick plant, as the brick requirements of western Newfoundland are now supplied from the mainland. The request was accepted, tne work to be performed under the START program with 100% funding by CANMET.

MATERIALS

Two samples of approximately 10 kg dry weight were supplied. The samples were identified as "Wild Cove 002" and "Wild Cove 005", reportedly taken from locations approximately 800 m apart and representing two types of clay in the deposit surrounding the Cove. The samples as-received were packed in sealed plastic bags to preserve their natural bank-moisture content.

Sample 002 appeared to be a mixture of smoothly tough-plastic red clay and some unconsolidated (weathered) surface material carrying organic impurities of grass and rootlets. It was subsequently found to contain a number of stones of igneous-type rock ranging from one to 4.5 cm maximum dimension: these appeared to be concentrated mostly in the weathered material, but the largest was found in the main body of plastic clay (perhaps distributed there by accident during sampling?). The presence of numerous smaller pebbles was also indicated during crushing.

Sample 005 is clearly a varved deposit, with thinly bedded seams of red plastic clay, brown silty clay and fine sand and silt. No stones were detected in the sample, but again the presence of small pebbles was indicated during crushing.

PROCEDURE AND RESULTS

CLAY PREPARATION

The samples were oven-dried at 105°C for 24 h. Representative aliquots were weighed before and after drying to determine the as-received moisture content. Sample 002 contained 26.8% water, Sample 005 contained 30.4% water, both calculated on the basis of dry weight of clay.

The samples were crushed to about one cm maximum dimension in a laboratory jaw crusher. During this operation the stones in sample 002 were readily detected and removed. The samples were then ground in a disc-type mill to pass ≈99% through a 10-mesh Tyler screen. The presence of a number of small pebbles or hard aggregates in both samples was clearly indicated by the noises emanating from the grinder.

PLASTICITY

The plastic nature of the clays was determined using the Brabender Plastograph following the normal procedures established in this laboratory: sample size, 200 g; rate of continuous water addition, 1% per minute. The plastograph curves are shown in Fig. 1.

Sample 002 displays a sharp initial peak, estimated to reach 2200 metre-grams of torque. This behaviour of clays is usually associated with a substantial content of very fine-grained pseudo-plastic material (rock flour), and is invariably associated with poor extrusion properties owing to laminar flow.

Sample 005, on the other hand, shows a broad consistency peak, reaching a level of only 560 m.g of torque, indicated by experience to be the bare minimum for satisfactory extrusion of mechanically sound bricks.

It was thus determined to include a further sample for investigation, viz., a half-and-half (wt %) mixture designated 025, expected to show intermediate plastic properties. As anticipated, the plastogram shows a maximum consistency of 1150 m.g torque and an optimum water of plasticity of about 22%.

PYROMETRIC CONE EQUIVALENT (PCE)

The PCE's (or heat softening temperature) of the three samples were determined in a laboratory down-draft furnace designed for such testing. Representative aliquots of each sample were plasticized with an appropriate

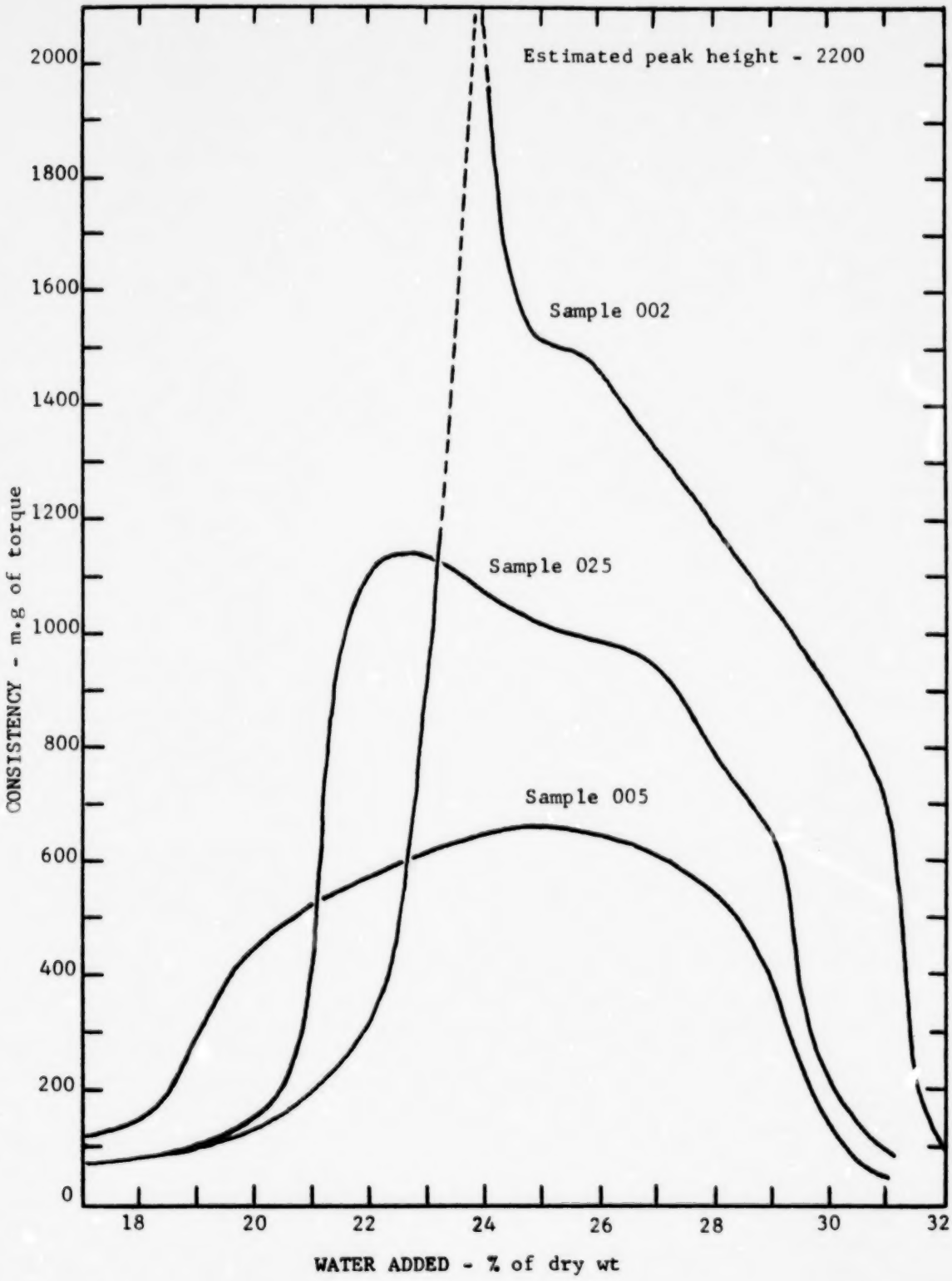

Fig. 1 - Plastograms of clays from Wild Cove, Newfoundland.

amount of water and formed into standard size cones (elongated trigonal prisms). The deformation end-point at a prescribed heating rate was determined in comparison to those of standard Orton cones of fixed end-point temperature.

The PCE's of the samples were: Sample 002, Cone 3^- (1145°C); Sample 005, Cone 6^+ (1205°C); Sample 025, Cone 5^- (1170°C).

EXTRUSION TESTS

Aliquots of 1500 g (dry wt) of each sample were prepared for extrusion, using optimum water additions deduced from the plastograms. The clay and water were thoroughly pre-mixed in a Hobart paddle-type mixer and extruded under vacuum with a Loomis hydraulic extrusion press through a 2.54 x 2.54 cm die. The extruded column was cut into lengths of ≈20 cm, and both ends of each bar were numbered for identification and shrinkage marks at preset spacing were applied.

As anticipated, Sample 002, containing 23.5% water, showed severe laminar flow, evident concentrically such that the corners of the bars were completely stripped off. Comensurate with its high measured consistency, the column was dense and tough and the pressure required for extrusion was a relatively high 5-6 tonnes.

Sample 005, with 21% water content, required only 1-2 tonnes pressure to extrude a column of excellent mechanical appearance. Except for some occasional tearing at the corners (attributed to the long former section of the die) extrusion appeared to be essentially by plug flow. However, the green briquettes were weak (poorly bonded) and so soft that bricks would surely suffer finger marking if manually handled or deformation if mechanically handled.

Sample 025, with 21% moisture, showed good smooth flow with only slight tearing at the corners (again, too long a die former) and produced a firm dense column. Pressure required for extrusion was a moderate, and normal, 3-5 tonnes.

DRYING BEHAVIOUR

One freshly extruded briquette from each sample was immediately placed in an oven preheated to 85°C. This rather severe exposure is used to indicate potential drying problems. On withdrawl from the oven after 5

minutes, none of the samples showed any cracking, indicative of safe drying behaviour in commercial conditions.

The remainder of the briquettes were allowed to air-dry over night, then final dried in a forced convection oven at 105°C for 24 hours. The distance between shrinkage marks was measured and drying shrinkages calculated. Average shrinkages of the samples, in % of wet length, were: Sample 002, 6.0%; Sample 005, 3.3%; Sample 025, 5.0%.

Dry Strength

The 20-cm dry bars were broken in flexure, using 3-point loading, in a Tinius-Olsen testing machine. Moduli of Rupture were calculated from:

$$MoR = \frac{3Pl}{2bd^2}$$

where P = applied load, l = length between the outer knife-edges, b = breadth, and d = depth.

The average MoR, with average deviation from the mean in brackets were: Sample 002, 43.64 MPa (12.31 MPa); Sample 005, 34.03 MPa (0.503 MPa); Sample 025, 53.01 MPa (4.543 MPa). Samples 005 and 025 produced essentially square, sharp fractures and reliable results. The type of fracture and individual strengths of bars made from Sample 002 was obviously affected by internal lamination planes; thus this set of briquettes recorded both the highest and lowest individual strengths, depending upon the degree of lamination within the fractured zone.

Firing Behaviour

Briquettes made from each sample were fired, in duplicate, in electrically heated laboratory kilns to each of 4 temperatures, selected to range from soft-fired to vitrified or slightly overfired. The degree of firing was demarked by standard Orton cones, crosschecked by thermocouples placed near the specimens. Heating rates were adjusted to reach the final temperature in about 18 hours, with cooling at the normal rate of the

furnace. Firing temperatures were: Cone 06 (991°C), Cone 04 (1050°C), Cone 02 (1101°C) and Cone 3 (1152°C).

The effect of firing temperature on fired properties was evaluated. The fired briquettes were measured and firing shrinkages were calculated, again on the basis of wet weight to be directly additive to drying shrinkage. Water absorptions were determined, both for 24 h cold soak and for 5 h boil. Saturation coefficients (C/B ratios) were calculated from the absorption data. The results are given below:

Fired Properties of Newfoundland Clays

Sample No.	Drying Shrinkage	Firing Temp	Fired Shrinkage	Absorption 24 h	Absorption 5 h boil	C/B
002	6.0%	Cone 06	1.3%	15.2%	15.9%	0.96
		04	3.1	8.7	9.1	0.9
		02	6.3	0.2	0.2	1.0
		3*	2.7	1.0	3.1	-
005	3.3%	Cone 06	0.0%	15.6%	18.0%	0.87
		04	2.3	10.4	13.2	0.78
		02	4.7	3.6	6.2	0.54
		3**	6.1	0.6	1.1	0.52
025	5.0%	Cone 06	0.5%	15.0%	16.1%	0.93
		04	1.5	10.1	11.5	0.87
		02	4.3	1.0	1.9	0.65
		3*	3.7	0.6	4.9	-

*Overfired, bloated
**Vitrified, slightly bloated

All samples fired to various shades of brick-red, in each case darkening with increasing firing temperature, varying from salmon at the lower temperatures to brownish red at vitrification. Sample 005 developed the most pleasing dark red colour at Cone 02. The colours of Sample 002 were marred by the presence of a white dryer scum: this should be controllable with additions of barium carbonate. Lesser amounts of scum were evident on Sample 025. Owing to differences in firing schedules and kiln atmospheres, darker colours should be expected in commercial kilns.

No fired strengths were measured owing to uncertainties in scaling up the data from briquette to full size brick geometry. However, all three samples were steel-hard at firing temperatures of cone 02 and up, and strengths should be on the order of those required for grade SW bricks.

DISCUSSION AND CONCLUSIONS

It is unknown whether the high moisture content of the samples as-received is a normal year-round condition or a seasonal phenomenon. If seasonal, the preferred clay preparation method would be to harvest the material in dry conditions for undercover storage: a simple roll disintegrator and differential double smooth roll would be sufficient. Drying brick clays is not cost-beneficial, hence if the moisture content is always high, resort to wet preparation would be required, using a wet-pan followed by a differential double smooth roll crusher. Wet preparation probably produces a better blend of dissimilar materials but continuous moisture control is more difficult.

Attention is also required with respect to the stone content of the clays, particularly Sample 002: hard stones as large or larger than the maximum size found in this sample could be expected to damage the processing equipment.

Sample 002, alone, is unsuited to the manufacture of clay products by any plastic process because of its poor flow properties, high combined shrinkages and short firing range for dense products. It is likely that bricks could be formed successfully by the dry press method, but this would result in increased firing shrinkages and further shortening of the firing range, rendering size control extremely difficult.

Sample 005, alone, is too soft and weak to handle successfully in the green state, although it shows acceptable firing shrinkages and fired absorptions and a moderately wide firing range for dense products.

Sample 025 appears to point the way to a successful solution. The evident die laminations could be controlled by use of lubricated dies with short former sections (commonly employed in the industry). The combined firing shrinkages are acceptable, as are C/B ratios in the harder fired specimens. The influence of Sample 002 is demonstrated in a short firing range for dense products.

Improved flow properties and widened firing range would be obtained by reducing the proportion of Sample 002 from one-half to one-third or one-quarter. Such a mixture, fired at temperatures as low as Cone 06, could be used to manufacture structural or partition tile (for interior or non-exposed applications) or flower pots. At firing temperatures of Cone 3±, it should be possible to produce facing bricks suitable for exposure to the climatic conditions prevailing in western Newfoundland and the Maritime Provinces.